Effects of different body postures on anthropometric measures

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Abstract. The shape and size of the human body is affected by the posture adopted in order to perform various activities. The human body is constantly changing and adapting to the movements executed in everyday life. As such, knowledge about the body changes that occur with the adoption of different postures is essential. Besides the obvious adverse health effects caused by spending long periods of time in certain postures, the adopted posture may influence people's interaction even with the simplest items such as clothing. For all these reasons, being able to determine the anthropometric changes related to different work postures is very important to occupational ergonomics. The main objective of this paper is to identify and quantify the body changes that occur with each of the postures adopted.

Keywords: Anthropometry · Working postures · Human body · Variations

1 Introduction

Fashion designers have to rely on anthropometric studies that represent target populations, considering their standing and static position. However, it can be difficult to find appropriate anthropometric data and the most frequent situation is to have anthropometric data that has been collected from populations that are noticeably different from the target populations [1]. In many countries the products are designed according to the extensive data available for military populations.

Unlike other consumer products, with dimensions based on combined anthropometric data from men and women, data needed for clothing design is very sensitive.

Body shapes and sizes vary according to many factors as gender, age and culture in ways that have an impact on clothing fit.

Additionally, anthropometric surveys are usually different in terms of population size, age groups, procedures used and, time of the measurements [2]. All these aspects can lead to a mismatch in the dimensions of the product and the user.

Some researchers have tried to determine the changes in shape and size of the human body that occur according to the posture adopted. For example, Carvalho, Duarte, Heinrich & Woltz [3] performed a comparative anatomical study between the

standing and sitting positions, analyzing the dimensional and postural alterations of the human body when sitting, in which they identified:

- Shrinkage of the trunk;
- Volume increase in the abdominal region;
- Variation in height, volume and inclination of the waist;
- Broadening of the hips;
- Redistribution of the muscular mass in the thighs.
- Increase of upper-back bending;
- Modification of the angular position of the elbow;
- Increase of the leg frontal length caused by the flexion of the knees.

Most of these postures can become uncomfortable for workers, especially when the clothes they wear are not adequate and cannot be adapted to the challenges of the tasks to be performed. As such, some of these challenges can be mitigated when wearing appropriate clothing, preventing health issues and increasing perceived comfort.

Frequently some discomfort in clothing can be felt with movement or when dynamic postures are assumed. When the body moves the dimensions change, for example the increase of the length on one side of a bending joint and the decrease of the length on the other side [4]. If the clothing does not increase in dimension over a bending joint, or binds where body dimensions decrease, it will restrict movement or intensify its difficulty creating discomfort.

Several studies evaluated the impact of the body changes in the clothing fit and comfort. Lotens [5] determined the ease needed in clothing for seven extreme postures. Cichocka, Bruniaux & Frydrych, [6] quantified body changes with movement for the shoulders, buttocks, arms, legs, elbows and knees. Aldrich, Smith & Dong [7] described garment distortions related to body movements. Lee & Ashdown compared [8] the variations in upper body measurements for three active postures. Choi & Ashdown [9] and [10] calculated the differences in body measurements between standing and sitting postures, finding an increase of waist girth by 8%; an increase of hip girth by 7%; a decrease of crotch girth by 16% and an increase of center leg length by 10% when in the sitting posture.

According to Cichocka, Bruniaux & Frydrych [11] developing a garment may be one of the most difficult problems in the field of textile engineering, and consequently, before designing a garment adapted to the human body, it is imperative to have an intimate knowledge of its morphology in order to create the final style successfully.

In this paper the anthropometric measurements of 50 workers were collected in different postures. The purpose of this was to quantify the variations that occur in the human body when different postures are adopted. Moreover, it allowed understanding how this variability will affect the clothing design in order to maximize fit and comfort.

2 Materials and Methods

Fifty participants volunteered to take part in this study; 12 of them were females and 38 were males. This sample had an average age of 36.49 ± 11.39 years old, an average height of 170.86 ± 69.3 cm and an average weight of 71.30 ± 10.70 kg.

The participants worked in four different companies/institutions – one research centre, one software development company, one industrial company and one university. A formal contact was established with the companies, inviting them to participate in the study. The participation in this study was voluntary and the management board of the company selected the participants. When contacted, the participants were informed of the detailed procedures and requirements of the test.

The data collection was performed by one certified anthropometrist that collected all the anthropometric data, using traditional anthropometry techniques (with a regular measuring tape and a Harpenden anthropometer). A total of 25 measurements were collected, representing the basic body measurements that are needed for the design of the base patterns [12]. Some of the measurements were collected in different postures to try to identify the modifications on the body that occur when people are not on the stationary standing position. These postures were selected to include postures where more significant differences were expected to be found and, as shown in Figure 1, were the following:

- P1: stationary standing with arms to the sides;
- P2: sitting with the knees bent at 90 degrees and feet touching the ground;
- P3: standing with arms to the front parallel to the ground;
- P4: standing with arms up in a 180-degree angle with the trunk;
- P5: standing with arms to the sides in a 90-degree angle with the trunk.

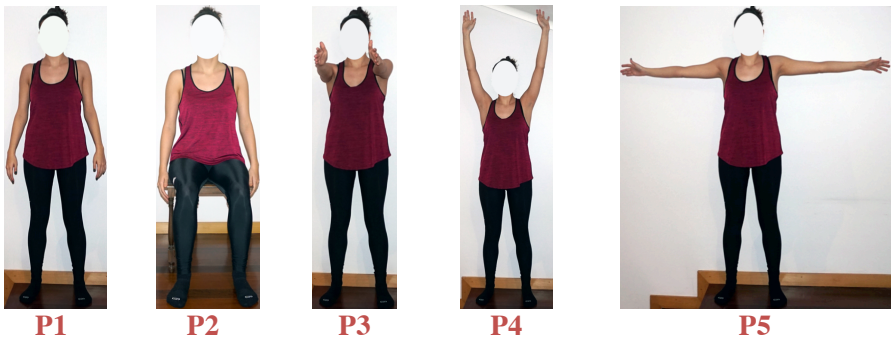

Fig. 1. Postures in which the measurements were taken (from P1 to P5).

The anthropometric measurements collected were divided in two categories: static (the ones collected in posture P1 and posture P2) and dynamic (the ones collected in the other postures, P3, P4 and P5) – Table 1.

Table 1. Measurements collected for the study.

Type	ID	Measurement	Posture	Type	ID	Measurement	Posture
Static	1	Neck base girth	P1	Dynamic	18	Waist girth	P1, P2
	2	Chest girth	P1		19	Abdomen girth	P1, P2
	3	Knee girth	P1		20	Hip girth	P1, P2
	4	Calf girth	P1		21	Thigh girth	P1, P2
	5	Ankle girth	P1		22	Leg length	P1, P2
	6	Arm girth	P1		23	Crotch length	P1, P2
	7	Forearm girth	P1		24	Across chest length	P1, P3, P4, P5
	8	Arm length	P1		25	Across back length	P1, P3, P4, P5
	9	Crotch length back	P2				
	10	Crotch length front	P2				
	11	Upper leg length	P2				
	12	Lower leg length	P1				
	13	Knee height	P1				
	14	Waist height	P1				
	15	Shoulder height	P1				
	16	Stature	P1				
	17	Weight	P1				

Error! Reference source not found. shows a representation of the measurements in the human body.

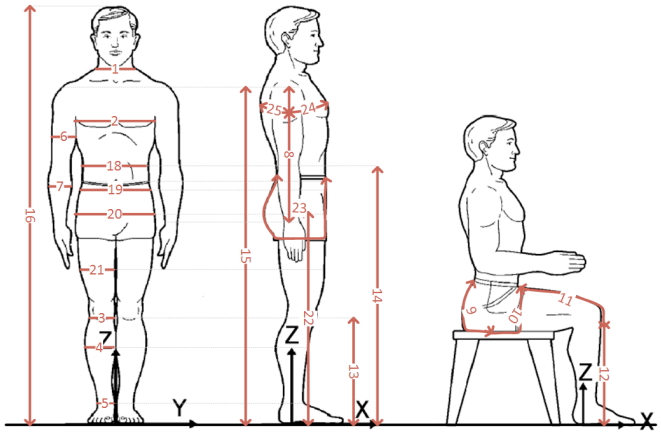

Fig. 2. Representation of the measurements taken on the human body.

Regarding the analysis of the data, descriptive statistics were calculated (mean and standard deviation), as well as the mean differences registered between the measurements collected in the static and in the dynamic postures. To analyze the meaning of these differences, a paired samples t-test was used. The significance level was set at 0.05 ($\alpha = 0.05$), meaning that body measurements with p values lower than 0.05 were considered to have significant difference between postures.

3 Results and discussion

Table 2 shows the means, standard deviations, minimum and maximum values for all measurements collected with all the 50 participants.

Table 2. Mean, standard deviation, minimum and maximum values of the body measurements considered (in mm).

Measurement	Mean	Standard Deviation	Maximum	Minimum
Neck base girth	396.2	25.2	457.0	338.9
Chest girth	994.4	86.2	1317.1	820.5
Knee girth	359.7	24.2	432.4	307.5
Calf girth	368.5	26.3	444.5	323.0
Ankle girth	243.3	24.1	331.6	210.0
Arm girth	306.1	34.4	397.0	230.0
Forearm girth	253.0	32.3	350.0	182.6
Arm length	541.4	38.2	650.0	473.5
Crotch length back	422.9	78.7	550.0	347.4
Crotch length front	250.5	59.5	395.0	202.6
Upper leg length	460.4	40.2	555.0	390.0
Lower leg length	431.8	90.1	550.0	250.0
Knee height	539.9	122.3	744.0	291.8
Waist height	1168.3	364.5	3610.0	957.2
Shoulder height	1415.6	87.5	1593.0	1248.7
Stature	1708.6	69.3	1830.0	1560.0
Weight	713.0	107.0	1003.0	518.0
Waist girth P1	831.5	94.3	1087.0	678.0
Waist girth P2	864.9	100.3	1161.0	706.0
Abdomen girth P1	918.3	99.6	1194.8	762.0
Abdomen girth P2	984.8	136.9	1331.2	765.0
Hip girth P1	982.5	65.1	1169.0	856.0
Hip girth P2	1020.2	66.6	1232.0	907.0
Thigh girth P1	488.3	41.4	607.0	430.0
Thigh girth P2	507.3	44.9	605.0	405.0
Leg length P1	891.3	117.2	1075.0	670.0
Leg length P2	894.4	87.8	1040.0	740.0
Crotch length P1	708.6	91.3	930.0	530.0
Crotch length P2	668.5	129.9	880.0	500.0
Across chest length P1	443.8	55.4	553.0	348.0
Across chest length P3	393.8	60.5	516.0	292.0
Across chest length P4	379.6	60.0	503.0	295.0
Across chest length P5	424.6	55.0	528.0	315.0
Across back length P1	503.4	55.5	600.0	369.0
Across back length P3	533.3	70.7	750.0	380.0
Across back length P4	528.2	70.1	660.0	338.0
Across back length P5	497.6	55.5	590.0	373.0

The results obtained demonstrate that there is a difference in the measurements according to the posture adopted. **Table 3** displays the mean difference registered (both

in mm as in percentage) when the posture changes. Positive values imply that the body measurement increases from P1 to the other posture (P2, P3, P4 or P5) while negative values indicate that the body measurement decreases with the posture.

Table 3. Mean differences between body measurements in different postures.

Measurement	**Mean Difference in mm (and percentage %)**		
Waist girth	+33.4 (+4.04%)*		
Abdominal girth	+63.9 (+6.96%)*		
Hip girth	+37.7 (+3.86%)*		
Thigh girth	+19.0 (+4.05%)*		
Leg length	+39.2 (+0.86%)*		
Crotch length	-26.5 (-5.57%)*		
Across chest length	-50.1 (-11.37%)**	-64.2 (-15.83%)***	-19.2 (-4.17%)****
Across back length	30.0 (+5.91%) **	24.8 (+4.82%) ***	-5.8 (-1.09%) ****

*P1 compared to P2; **P3 compared to P1; ***P4 compared to P1; ****P5 compared to P1

As it can be seen, there are some measurements with considerable differences according to the posture adopted. For example, raising the arms upwards makes the across chest length decrease about 16%, when compared to the regular static standing posture. As all the body measurements are related to one another, consequently, the across back length increases about 5%.

Most of the measurements had a large variation. However, there are other measurements that only change slightly, as is the case of the leg length, which only increases about 1%.

The results of the paired samples t-test (shown in **Table 4**) demonstrated that for the majority of the comparisons there is a statistically significant difference (p<0.05) between the measurements.

Table 4. Results of the paired-samples t-test.

Measurement		**t**	**df**	**Sig. (2-tailed)**
Pair 1	Waist girth P1 – Waist girth P2	-9.643	49	<0.001*
Pair 2	Abdomen girth P1 – Abdomen girth P2	-9.088	47	<0.001*
Pair 3	Hip girth P1 – Hip girth P2	-14.481	49	<0.001*
Pair 4	Thigh girth P1 – Thigh girth P2	-4.307	49	<0.001*
Pair 5	Leg length P1 – Leg length P2	-0.496	49	0.622**
Pair 6	Crotch length P1 – Crotch length P2	2.761	49	0.008**
Pair 7	ChestP1 – ChestP3	12.404	49	<0.001*
Pair 8	ChestP1 – ChestP4	9.452	49	<0.001*
Pair 9	ChestP1 – ChestP5	4.774	49	<0.001*
Pair 10	BackP1 – BackP3	-5.677	49	<0.001*
Pair 11	BackP1 – BackP4	-5.229	49	<0.001*
Pair 12	BackP1 – BackP5	2.130	49	0.038**

*p<0.05 statistically significant difference; ** p>0.05 no statistically significant difference

Amongst all the pairs, the only ones that did not have a statistically significant difference were the leg length, the crotch length and the across back length in P1 and P5. However, it should be noted that the crotch length pair showed a value very close to

0.05. This means that if the significance level was set at a higher value (e.g. 0.09 rather than 0.05) the difference between this pair of measurements would be considered to have a statistically significant difference.

A previous study, conducted by the authors to the same sample by applying questionnaires, revealed to be in accordance with the data obtained from the anthropometric measurements [13]. The areas pointed-out as areas of limitation of movements in the questionnaire were the ones measured in the study in distinct postures – sleeves; armholes; shoulders; chest and back, evaluated through the across chest length and across back length; waist evaluated through the waist girth; hip evaluated through the hip girth; thighs evaluated through the thigh girth; legs evaluated through the leg length. Additionally, all these areas presented a considerable variation with the change in the posture adopted. These changes are even visible to the naked eye, as demonstrated in Fig. 3 and Fig. 4, where it is clear that when the posture changes the body shape and size varies accordingly.

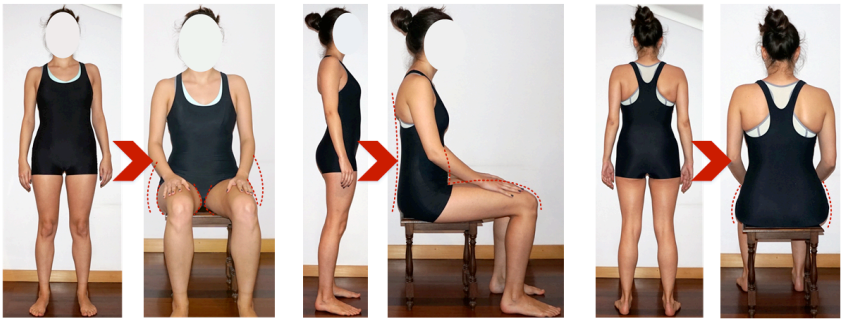

Fig. 3. Changes in the body that occur from standing to sitting.

From standing to sitting, i.e., from P1 to P2, the variations occur mostly in the lower part of the body. These variations include: (i) the increase in the breadth of the hip and thighs due to the pressure exerted by the stool; (ii) the reduction in the spinal column's arch due to the rotation of the hip forewords; (iii) the augmentation of the protuberance in the abdominal region; and (iv) the increase in the leg length in the front of the leg over the knee caused by the bending of the knees.

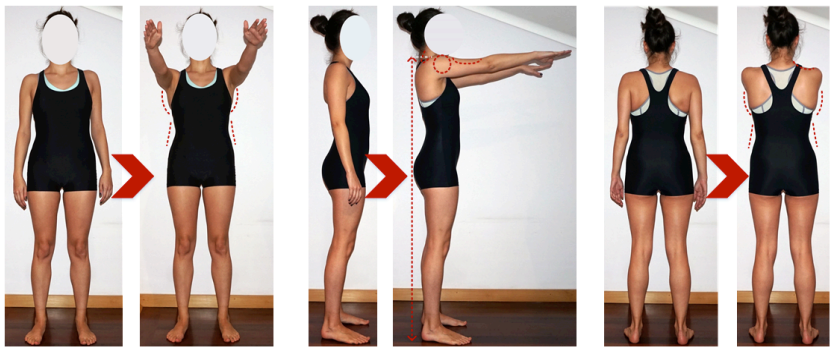

Fig. 4. Changes in the body that occur from P1 to P3.

When changing from P1 to P3 the variations occur solely in the upper part of the body. Some of these variations include: (i) the increase in the shoulder height; (ii) the reduction of the waist curvature (more evident in women); (iii) the decrease in the chest breadth; (iv) the intensification of tension in the shoulders and arms regions (especially in the deltoid, biceps and trapezius muscles); and (v) the increase in the back breadth.

In fact, all the measurements in this study, except the leg length, presented a statically significant difference when the posture changes. This makes it easy to understand that the feeling of comfort with clothing that users get is not the same when they are in different dynamic postures. Despite the variation in the measurements was almost all below 10%, it is still a considerable difference that may have a great impact on garment fit and comfort.

4 Conclusions

People are becoming more and more sedentary but there is still the need to perform some movements and adopt some postures during leisure and work activities that may be negatively influenced by clothing. Some examples of those types of postures are the ones presented in this study, which proved to have quite a meaningful impact on the anthropometric measurements and consequent fit and comfort of clothing items.

The significance of the differences quantified here can also be demonstrated with other test (e.g. measurement of compression forces exerted by clothing when in different postures), where it would be possible to see that clothes that are not designed taking in consideration the dynamic postures affect in great part the compression imposed to the user, limiting his/her movements and causing discomfort.

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